GUIDELINES FOR THE DESIGN OF STABILIZED PAVEMENTS

(Part II)

INDIAN ROADS CONGRESS
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CONTENTS

GUIDELINES FOR THE DESIGN OF STABILIZED PAVEMENTS

1 INTRODUCTION

1.1 Stabilization has been use practice for many years now and has made vast progress in improving the quality of pavements, as a result recent year have shown a rapid progress in stabilization. The age long technique is not limited to subgrade or embankment any more and has paved its way to the pavement layers like sub-base and base and in some special cases even in wearing course.

1.2 IRC:SP:89-2010, deals with Soil and Granular Material Stabilization using Cement, Lime & Fly Ash, which are traditionally being used as stabilizers to improve the strength and durability characteristics of various types of soils and granular materials in pavement structure and termed as Conventional Stabilizers (CS) in this document. In recent past, a number of companies are promoting different types of Commercial Chemical Stabilizers (CCS) in the market. The companies indicate that such stabilizers are special chemical compounds, which have been evolved after a long research and should be mixed with cement to enhance the strength and durability characteristics of soil cement mix. The dosage of such CCS to be mixed varies from 0.5 per cent to 5.0 per cent of cement content. These chemical stabilizers are available either in powder form or in liquid form. The categories of different CCS available in the country are as follows:

a) Natural Inorganic Powder Binders
b) Water Repelling Nano Chemicals
c) Waste Oil
d) Petroleum Based Products
e) Liquid Stabilized Products
f) Synthetic Polymers
g) Sulphonate Lignin etc.

1.3 Some companies mix these chemical compounds in cement itself at the manufacturing plant and sell such products (cement mixed with admixtures), with a commercial name. Such products are ready to use and therefore can be directly mixed with soils or granular materials for site specific requirements in the desired quantity as determined by detailed laboratory/field tests. However, some companies provide the CCS separately, which is required to be mixed at site with cement in a manner as suggested by the company before being used with soil or granular materials. It is claimed that the materials stabilized with CCS not only yield better strength but result in improved elastic and thermal properties of the mix and therefore less prone to cracking and shrinkage cracks. Since long term performance of roads constructed with such special products is not available, it becomes difficult to accept such products for large scale application.

1.4 In order to promote stabilizers, this document has been brought out as an addendum to IRC:SP:89-2010 as IRC:SP:89 (Part II) to deal with various aspects of Commercial Chemical Stabilizers/Conventional Stabilizers. The addendum deals with issues such as mechanism for acceptance of CCS/CS, test requirements, material characterization and design aspects to be looked into while selecting any CCS/CS for the purpose of soil/granular materials stabilization and/or construction of cementitious base and cementitious sub-base layers or to improve CBR values of the sub-grades. Since long term performance of roads constructed with such materials is not known, a conservative approach is being suggested.

1.5 The task of preparation of IRC:SP:89 (Part II) "Guidelines for the Design of Stabilized Pavements" was assigned to Composite Pavement Committee (H-9). The draft was prepared by the subgroup comprising Dr. Sunil Bose, Shri Sudhir Mathur, Shri Bidur Kant Jha and Shri Mohit Verma. The draft was deliberated in a series of meetings. The H-9 Committee finally approved the draft document in its meeting held on 9th September, 2017 and decided to send the final draft to IRC for placing before the HSS Committee.

The Composition of H-9 Committee is as given below:

Bongirwar, P.L.	……	Convenor
Bordoloi, A.C.	……	Co-Convenor
Thakar, Vikas	……	Member-Secretary

Members

Arora, V.V.	Kumar, Satander
Bhattacharyya, Shantanoo	Nayak, Sanjay
Bose, Dr. Sunil	Nirmal, S.K.
Chakraborty, Raj	Pateriya, Dr. I.K.
Das, Prof. (Dr.) Animesh	Sahoo, Prof. (Dr.) U.C.
Deshmukh, Dr. V.V.	Sarma, Sivarama
Deshmukh, Yuvraj	Talukdar, Biraj
Jain, L.K.	Thombare, Vishal
Jain, R.K.	Verma, Mohit
Jha, Bidur Kant	Rep. of UltraTech Cement Ltd. (Jain, A.K. upto 17.08.2016 thereafter Ramachandra, Dr. V.)
Kumar, Binod	

Corresponding Members

Pandey, Prof. (Dr.) B.B.	Shukla, R.S.

Veeraragavan, Prof. (Dr.) A.

Ex-Officio Members

President, Indian Roads Congress	(Pradhan, N.K.), Engineer-in-Chief cum Secretary, Works Department, Odisha
Director General (Road Development) & Special Secretary to Govt. of India	(Kumar, Manoj), Ministry of Road Transport & Highways
Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

The Highways Specifications and Standards Committee considered and approved the draft document in its meeting held on 13th October, 2017. The Executive Committee in its meeting held on 2nd November, 2017 considered and approved the same for placing it before the Council. The Council of IRC in its 213th meeting held at Bengaluru on 3rd November, 2017 considered and approved the draft IRC:SP:89 (Part II) "Guidelines for The Design of Stabilized Pavements" for printing.

2 MECHANISM OF ACCEPTANCE FOR CCS

2.1 The following two documents shall be checked and carefully examined before accepting any commercial stabilizers for field trial:

- **Base Document of Product**

CCS varies in composition and effectiveness. The addition of CCS in soil and/or granular material may result in reduction of plasticity, change in gradation and improvement in strength and durability characteristics of the mix. Therefore, the Engineer must thoroughly examine the base documents provided by the supplier/company for such unproven products. The document should provide the basic information such as:

(i) Broad chemical composition
(ii) Place of manufacturing
(iii) Locations of successful field applications and
(iv) Other relevant information pertaining to the product

The document should also bring out in terms of test results, the advantage of using CCS vis-a-vis conventional stabilizers such as cement or lime-flash-cement etc. in improving the strength and durability characteristics of the soil/granular materials proposed to be used for road works. It must be ensured that the CCS materials do not contain toxic/heavy metals which due to leach ability may affect the soil, plants and ground water. The test methods for obtaining the test results and certificate for the same is given in **Annexure-I**.

- **Certificate of Usage**

Certificate of Usage from the Country of Origin with successful project reports and field evaluation reports on roads in our climatic conditions. If the product is in existence in India for more than 2 years and has been tested for some experimental road trials, the supplier should also furnish the following information:

i. Certificate of usage in India in last 2 years.
ii. Success rate of the new technology in Indian condition as per last 2 years data.
iii. Quantum of work completed in Government Projects using new technology.
iv. Field Evaluation report by Government Institutes/Organizations on roads constructed with new technology in different regions with varied climatic conditions viz., sub-zero, Snow-bound, high rain fall conditions, etc.

For Proven Products

In case the CCS has been already proven for successful usage in different weathering conditions in India for any category of roads, test reports of such road tracks done should be furnished and shall be alone adequate for its considerations if a separate fatigue equation for such stabilizer is developed through reputed Institute like IIT's, NIT's, CRRI etc., the same can be used at the discretion of the user.

3 MATERIAL CHARACTERIZATION

3.1 Requirement for Soil Modification/Subgrade Improvement

CCS/CS can be used for soil modification or improvement of subgrade soil or for construction of cementitious base/sub-base layers meeting the requirements as laid-down in the latest edition of IRC:37. It is recommended from economic consideration that mix-in-place methods of construction be used for subgrade improvement. The main requirement for CCS/CS modification or stabilization of subgrade soils shall remain the same as given in Table 6 of IRC:SP:89-2010. In case the subgrade soil is highly plastic, it can be modified with lime and/or flyash before being mixed with CCS/CS. The technical requirements for lime and flyash modification for subgrade improvement shall remain the same as given under Clause 4.3 to 4.6 in IRC:SP:89-2010.

3.2 Requirement for Stabilized Sub-base/Base

Materials which shall be considered for the construction of cementitious sub-base/base layers in a pavement structure stabilized with CCS/CS are as given below:

i. All types of aggregates including marginal aggregates*
ii. Reclaimed Asphalt Pavement Material
iii. Reclaimed Concrete Pavement Material

iv. Industrial Waste

v. Mines Waste

vi. Construction and Demolition Wastes

vii. All types of soil-granular materials mixes having PI<20 for sub-base and PI<10 for base

It is required that the materials shall conform to the gradation as mentioned in **Table 1**. In case the materials do not meet the gradation and other physical properties but satisfying the strength, durability with residual strength and toxicity, shall be considered after exhaustive research and development by any reputed Institute/Organization like IIT's, NIT's, CRRI etc.

*Marginal Aggregate: A marginal materials can be defined as materials which do not in their present form possess quality levels as defined by current highway standards sufficient for their use as various pavement structural components including surfaces, bases, and/or subbases. Aggregate produced from a more weathered or weather prone rock, or hard rock containing weathered seams or weaker sedimentary rocks, which after processing contains moderate or highly plastic fines, is susceptible to weathering and when compacted will produce a soaked C.B.R. value between 40 per cent and 100 per cent.

Table 1 Gradation Requirements for Sub-base and Base Layer Material

<table>
<tr><th rowspan="2">Sr. No.</th><th rowspan="2">Material</th><th colspan="3">Gradation Reference</th></tr>
<tr><th>Base</th><th>Sub-base</th><th>Specification</th></tr>
<tr><td>i.</td><td>All types of aggregates including marginal aggregates</td><td rowspan="4">Table 400-4, Clause 403.2.2</td><td rowspan="4">Grading IV, Table 400-1, Clause 401.2</td><td rowspan="6">Specification for Road and Bridge Works, Ministry of Road Transport & Highways</td></tr>
<tr><td>ii.</td><td>Reclaimed Asphalt Pavement Material</td></tr>
<tr><td>iii.</td><td>Reclaimed Concrete Pavement Material</td></tr>
<tr><td>iv.</td><td>Industrial, Construction and Demolition Wastes</td></tr>
<tr><td>v.</td><td>Mines Waste</td><td colspan="2">Table 400-3, Clause 402.3.2</td></tr>
<tr><td>vi.</td><td>All types of soil having PI<20 for sub-base and PI<10 for base</td><td colspan="2">Table 400-3, Clause 402.3.2</td></tr>
</table>

3.3 Test Requirements

It shall be noted that CCS/CS can be toxic and may pollute the soil, plant/human/animal/aquatic life and underground water through leaching and hence every CCS/CS must be checked for presence of heavy metals, toxicity and leaching with reference to **Annexure-I**. CSIR laboratory at Lucknow has the facility of conducting tests there may be few accredited laboratory having the facility to conduct the test.

All the properties of material to be stabilized with CCS/CS and intended to be used in various layers of the pavement structure shall be checked as per IRC:37 & IRC:SP:89-2010 and the relevant clauses of MoRTH Specifications for Road and Bridge Works, 2013, along with the following considerations:

i. For CCS/CS stabilized sub-base material, the durability shall be checked by the Method 1, Clause 4.7.2, IRC:SP:89-2010.

(It may please be noted that this test has not been specified for cement stabilized sub-bases.)

ii. For CCS/CS stabilized base material, the durability shall be checked by the Method 2, Clause 4.7.2, IRC:SP:89-2010. This test is as per ASTM D-559 for wetting and drying and ASTM D-560 for freezing and thawing. Freezing and Thawing procedure is required to be followed, if the stabilization is to be done in snow bound areas or where the minimum temperature is under sub-zero conditions. Refer **Annexure-II A** and **B** for details of tests.

iii. As specified by AASHTO and ASTM, a brush is being used in a standardized manner to evaluate material loss in the durability test. A mechanical brushing apparatus has been developed by CSIR, South Africa that would brush the specimens using a consistent effort. However, such equipment is not widely available in India therefore either of the brushing methods can be adopted as per the availability. The brushing apparatus is shown in **Fig. 1** below:

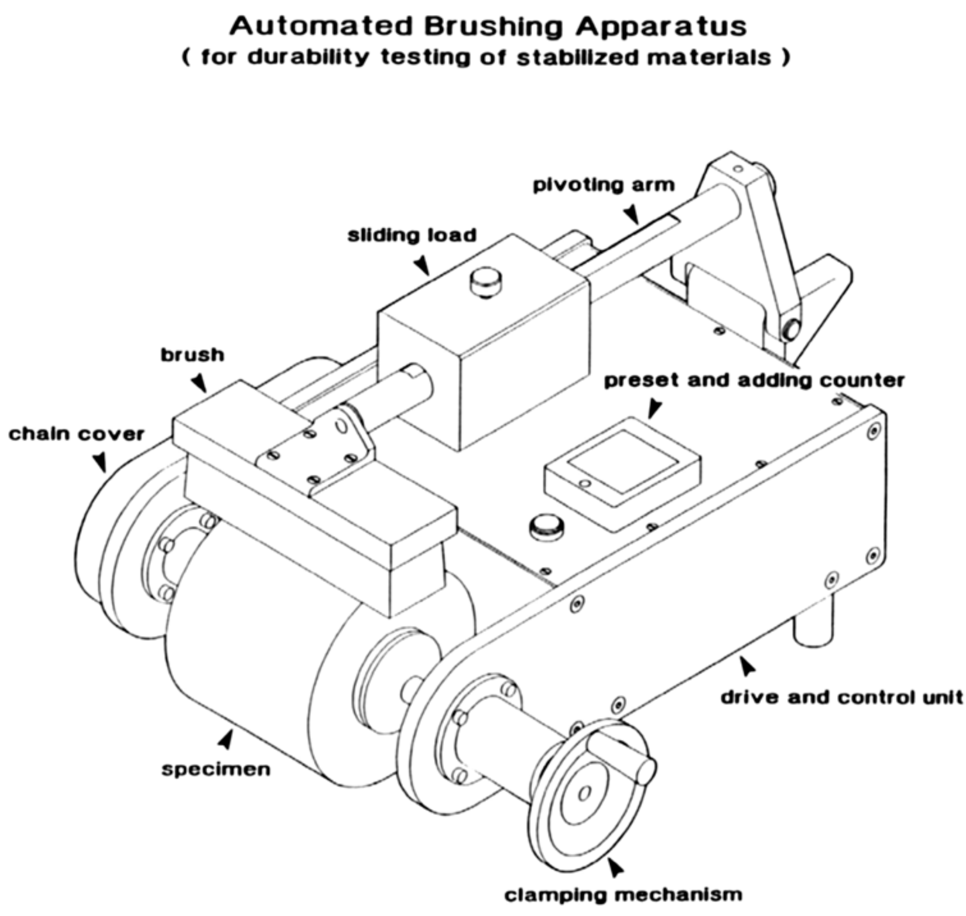


Fig. 1 Automated Brushing Apparatus

3.4 Requirement for Crack Relief Layer on CCS/CS Stabilized Base Layer

A crack relief layer shall be provided on CCS/CS stabilized base layer designed for traffic >=2 MSA. The crack relief could be either Aggregate Interlayer or Stress Absorbing Membrane Interlayer (SAMI) or emulsion stabilized/foam bitumen layer as allowed in IRC:37.

4 DESIGN METHODOLOGY FOR STABILIZED PAVEMENTS USING CCS/CS

4.1 The design methodology for CCS/CS stabilized pavements shall remain the same as provided in IRC:37. The following types of pavement with CCS/CS can be considered with bituminous surfacing and a crack relief layer in terms of Aggregate or Stress Absorbing Membrane Interlayer (SAMI):

- Stabilized Bases with Stabilized Sub-bases
- Stabilized Bases with Granular Sub-bases
- Granular Bases with Stabilized Sub-bases

4.2 Design Considerations for Sub-base and Base

Elastic Modulus: The relevant design parameter for bound sub-bases is the elastic modulus E, which can be estimated from the unconfined compressive strength of the material. The elastic modulus must be calculated by the following equation:

MR = 1000 x UCS for Rapid Hardening CS

MR = 750 x UCS for Slow Hardening CCS/CS

Where, E = Elastic Modulus of Stabilized Material

UCS = Unconfined Compressive Strength in MPa (7 and 28 days for Rapid Hardening & Slow Hardening Stabilizers respectively)

For design, 20% of E value derived from above given relation shall be taken. In case the elastic modulus is derived by 4 point beam testing with dynamic loading machine, the E value for design shall be taken directly with a minimum factor of safety of 1.5. The detailed procedure of testing & calculating elastic modulus value by 4 point Beam testing is given in **Annexure – II B**. However in this case the E value should be restricted to 1700 Mpa.

Flexural strength can be taken as 20% of UCS

Bound Sub Base Layer: Since the sub-base acts as a platform for construction traffic, low strength sub-base is expected to crack during construction, therefore for such cases, a design value of 600 MPa is recommended for design, though the modulus value as calculated by equation (1) may be in the range of 2000 MPa to 4000 MPa. The Poisson's ratio may be taken as 0.25. The CCS/CS stabilized layer shall be cured for minimum 15 days before the construction of the subsequent layer. If the stabilized sub-base layer have UCS in the range of 0.75 to 1.5 MPa, the recommended E value for design shall be 400 MPa.

Bound Base Layer: Flexure strength of a CCS/CS stabilized base is critical to the satisfactory performance of a bituminous pavement. Stabilized base layer may consist of soil or aggregate or soil-aggregate mixture stabilized with CCS/CS. It is required that stabilized mix should give a minimum strength of 4.5 to 7 MPa. It is recommended that the laboratory strength shall be at least 1.1 times higher than the design strength due to variability of construction in field. The upper limits of E value for base layer is restricted to 1400 and 1700 MPa by UCS and Beam method respectively. The fatigue strength is required for carrying out the fatigue damage analysis of CCS/CS treated base. Cumulative damage analysis as suggested in IRC:37 shall be carried out.

4.3 Pavement Design Procedure

4.3.1 The design procedure as provided in IRC:37 including cumulative damage analysis shall be followed with design parameters as proposed above. There can be large number of combinations for a good pavement depending upon the availability of materials. Some of the typical sections are given in **Annexure - III**.

5 CONSTRUCTION PRACTICES

5.1 The construction of CCS/CS stabilized layer follow the same basic procedure as explained in Chapter 5 of IRC:SP:89-2010. Two methods of stabilization as indicated below can be used:

1. Mix-in-place Stabilization
2. Plant-mix Stabilization

5.2 The procedure explained in above given reference shall be followed with following considerations:

For Mix-in-place Stabilization, specialized stabilization machinery shall be used capable of providing in-situ rock/boulder crushing-cum-pulverizing-cum-homogenizing features and for a constant depth/uniform operation. Manual mixing methods using labour/agriculture based methodology shall not be permitted except for low volume roads, where the depth of mixing of loose soil with the additive is not more than 100 mm-120 mm. Some of the recommended specialized machinery types are given in **Annexure - IV**.

For Plant-mix Stabilization, calibration of plant (Concrete batch mix/WMM) with the CCS shall be done to achieve the proper homogeneity of all the material as per specified combinations.

Success of stabilization technology depends on effective mixing of ingredients including stabilizers hence good quality equipment is must. Dosage of admixtures /stabilizers could be less than 3 per cent for few products hence intimate mixing through good effective equipment is essential.

6 PERFORMANCE BEHAVIOR

6.1 The resilient modulus and permanent deformation are important properties and shall be evaluated. The performance evaluation shall include the following field testing:

a) Resilient Modulus of different layers by Falling Weight Deflectometer (FWD) or by means of extracting cores from the 28 days cured layers for UCS testing to arrive at E-Values.

b) Deformation of different layers by Ground Penetrating Radar (GPR)

c) Surface Irregularities by Visual Inspection

6.2 Manufacturer of a CCS shall submit report on performance evaluation done by reputed Government Organization/Institution like NIT's, CRRI, IIT's or any NABL approved laboratory.

6.3 The performance evaluation report of roads constructed with such stabilizers shall be evolved after two years of trial with a frequency of two times every year.

6.4 Routine visual observations shall be taken and recorded monthly.

ANNEXURE-I

TOXICITY LEACHING TESTING ON STABILIZERS MIXED WITH SOIL

(Refer Clause 2.1 and 3.3)

The study shall be conducted according to the USEPA Guidelines (1311 of July 1992) for Toxicity Characteristics Leaching Procedure (TCLP).

TCLP is a soil sample extraction method for chemical analysis. When a material is disposed in landfills, hazardous substances contained in them may enter the environment. So to classify that material as hazardous, the regulatory test TCLP determines the quantity of hazardous substances leaching from a material under simulated conditions. If the levels of the hazardous chemicals are below TCLP limits for that particular chemical entity, the material can be disposed off in a municipal landfill without any treatment. If the levels exceed the limits, then the material has to be disposed off in a secured landfill or has to undergo further treatment for neutralization or stabilization.

The stabilizer shall be mixed with dried and sieved soil in recommended w/w ratio, water added, mixed thoroughly and can be casted in proctor moulds. Water containing mixed spiking solution of chromium, nickel, copper and lead shall be added in another set of samples. This shall be carried out as per IS 4332 part 3. The Stabilized samples shall be extracted in closed vessels with the leaching solution at pH 2.88 ± 0.05 as per TCLP protocol at 30 ± 2 rpm for 18 ± 2 hours at ambient temperature (23 ± 2°C). The resultant leachates shall be filtered, processed and analysed on Atomic Absorption Spectrometer for different metals using standard protocols (APHA, 2005). All the leaching studies shall be done in triplicate and the mean results shall be present.

The moulds of soil samples along with the controls shall be crushed, dried, sieved and tested for the leaching of metals (Chromium, Nickel, Lead and Copper) as per TCLP of USEPA (1311 of July 1992). The results shall indicate the levels of all the metals in reference with limits prescribed by USEPA for TCLP.

The testing shall be done by any organization/institution working under CSIR like Indian Institute of Toxicology Research, Lucknow and National Environmental Engineering Research Institute, Nagpur etc.

ANNEXURE-II A
DURABILITY TESTING FOR STABILIZED MATERIALS

(Refer Clause 3.3)

To determine the resistance of compacted stabilized materials to repeated adverse weather conditions. The test procedure is followed as per IS Code IS: 4332 (Part IV): Methods of test for stabilized soils: wetting and drying, freezing and thawing tests for compacted soil-cement mixtures.

Procedure for Wetting and Drying

A representative sample weighing about 20 kg or more of the thoroughly mixed material shall be made to pass through 20 mm and 4.75 mm: IS Sieves, separating the fractions retained and passing these sieves. Care shall be exercised so as not to break the aggregates while pulverising. The percentage of each fraction shall be determined. The fraction retained on 20 mm IS Sieve shall not be used in the test. The percentage of soil coarser than 4.75 mm IS Sieve and the percentage of soil coarser than 20 mm IS Sieve shall be determined. The ratio of fraction passing 20 mm IS sieve and retained on 4.75 mm IS Sieve to the soil passing 4.75 mm IS Sieve shall be determined. The material retained on and passing 4.75 mm IS Sieve shall be mixed thoroughly in the determined proportion to obtain about 16 kg of soil sample. A representative sample weighing approximately 16 kg of the thoroughly mixed material shall be taken. The soil, potable water and required amount of CCS/CS shall be mixed properly. The mixture should be broken up without reducing the natural size of individual particles. The specimens shall be formed by immediately compacting the soil-cement mixture in the mould (with the collar attached) and later trimming the specimens. In addition the tops of the first and second layers shall be scarified to remove smooth compaction planes before placing and compacting the succeeding layers. This scarification shall form groove at right angles to each other approximately 3 mm in width and 3 mm in depth and approximately 6 mm apart. During compaction, a representative sample of the soil-CCS/CS mixture weighing not less than 100 g shall be taken from the batch for moisture content determination. The compacted specimens shall be weighed with the mould. The specimens shall then be removed from the mould. The oven-dry density in g/cm^3 shall be calculated. The specimens shall be identified suitably as No. 1 and 2. These specimens may be used to obtain data on moisture and volume changes during the test. Two more specimens shall be similarly formed and their moisture content and dry density be determined. These specimens shall be identified as No. 3 and 4 and used to obtain data on soil-CCS/CS losses during the test. The average diameter and height of specimens No.1 and 2 shall be measured and their volume shall be determined. All the four specimens shall be placed on suitable carriers in the moist chamber and protected from free water for a period of seven days. Specimens No. 1 and 2 should be weighed and measured at the end of the seven-day period to provide data for calculating their moisture content and volume.

At the end of the storage in the moist room, the specimens shall be submerged in potable water at room temperature for a period of 5 h, refer **Photo 1** and removed. Specimens No. 1 and 2 shall be weighed and their dimensions measured. All four specimens shall then be placed in an oven at 70°C for 42 h and removed. Specimens No. 1 and 2 shall be weighed and their dimensions measured again. Specimens No. 3 and 4 shall be given two firm strokes on all areas with the wire-scratch brush. The brush shall be held with the long axis of the brush parallel to the longitudinal axis of the specimen or parallel to the ends as required for covering all areas of the specimen. These strokes shall be applied to full height and width of the specimen with a firm stroke corresponding to approximately 1.4 kg. 18 to 20 vertical brush strokes may be required to cover the sides of the specimen twice and four strokes may be required at each end, the above process constitute one cycle (48 h) of wetting and drying. The specimens shall again be submerged in water and the same procedure continued for 12 cycles. Testing of No. 1 and 2 specimens may be discontinued prior to 12 cycles should the measurements become inaccurate due to soil-CCS/CS loss of the specimen. After 12 cycles of test, the specimens shall be dried to constant weight at 110°C and weighed to determine the oven-dry weight of the specimens. The data collected will permit calculations of volume and moisture changes of specimen's No. 1 and 2, and the soil-CCS/CS losses of Specimen's No. 3 and 4 after the prescribed 12 cycles of test.

For Specimen's No. 1 and 2 the difference between the volumes of specimens, refer **Photo 2**, at the time of moulding and subsequent volumes as a percentage of the original volume should be calculated. The moisture content of Specimens No.1 and 2 at the time of moulding and subsequent moisture contents should be calculated as a percentage of the original oven-dry weight of the specimen. The oven-dry weight of Specimen's No. 3 and 4 shall be corrected for water that has reacted with the CCS/CS and soil during the test and is retained in the specimen at 110°C, as follows:

$$\text{Corrected oven-dry weight} = W_d \times 100/(w+100)$$

Where,

W_d = oven-dry weight after drying at 110°C, and

w = percentage of water retained in specimen.

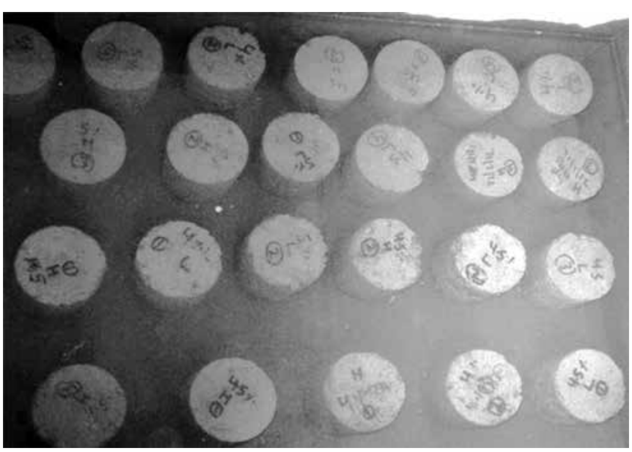


Photo 1

Photo 2

Durability Test in Progress (Wetting and Drying)

The percentage of water retained in the Specimens No. 3 and 4 after drying at 110°C for use in the above formula may be assumed to be equal to the average percentage of water retained in specimen No. 1 and 2. The soil cement loss of specimens MO. 3 and 4 shall be calculated as a percentage of the original oven-dry weight of the specimen as follows:

Soil cement loss, percent = A/B x 100

Where,

A = original calculated oven-dry weight minus final corrected oven-dry weight

B = original calculated oven-dry weight.

Procedure for Freezing and Thawing

The soil sample and specimens shall be prepared in accordance with the procedure given in wetting and drying.

At the end of the storage in the moist room, water saturated felts about 5 mm thick, blotters or similar absorptive material shall be placed between the specimens and the carriers. The assembly shall be placed in a freezing cabinet having a constant temperature not warmer than -23°C, refer **Photo 3** and **4** for 24 h and removed. The No. 1 and 2 Specimens shall be weighed and measured. The assembly should then be placed in the moist chamber or suitably covered container having a temperature of 25°C to 30°C and a relative humidity of 100 per cent for 23 h and removed. Free potable water shall be made available to the absorbent pads under the specimens to permit the specimens to absorb water by capillary action during the thawing period. The No. 1 and 2 Specimens shall be measured and weighed. Specimens No. 3 and 4 shall be given two firm strokes on all areas with the wire-scratch brush. The brush shall be held with the long axis of the brush parallel to the longitudinal axis of the specimen or parallel to the ends as required for covering all areas of the specimen. The strokes shall be applied to the full height and width of the specimen with a firm stroke corresponding to approximately 1.4 kg. Eighteen to twenty vertical brush strokes are required to cover the sides of the specimen twice and four strokes are required on each end. After being brushed, the specimens shall be turned over end for end before they are placed on the water saturated pads. The specimens shall be placed in the freezing cabinet and the procedure continued for 12 cycles. The No. 1 and 2 Specimens may be discontinued prior to 12 cycles should the measurements become inaccurate due to soil- CCS/CS loss of the specimen. After 12 cycles of test, the specimens shall be dried to constant weight at 110°C and weighed to determine the oven-dry weight of the specimens. The data collected will permit calculations of volume and moisture changes of Specimens No.1 and 2 and the soil-cement losses of Specimens No. 3 and 4 after the prescribed 12 cycles of test. The volume and moisture changes and the soil-CCS/CS losses of the specimens should be calculated as given in wetting-drying procedure.

Photo 3

Photo 4

Durability Test in Progress (Freezing and Thawing)

Report: The report should include the following:

a) The designed optimum moisture and maximum density of the moulded specimens.

b) The moisture content and density obtained in moulded specimens.

c) The designed CCS/CS content, in per cent, of the moulded specimens.

d) The CCS/CS content, in per cent, obtained in moulded specimens.

e) The maximum volume change, in per cent, and maximum moisture content during test of Specimen's No. 1 and 2.

f) The soil- CCS/CS loss, in per cent, of Specimen's No. 3 and 4.

g) Residual Strength, UCS test shall be carried out on the specimen remained after 12 cycles of wet/dry or freeze/thawing. The residual UCS strength shall not be less that 20 per cent of 28 days UCS strength.

h) The following limits of mass loss for different materials recommended by PCA(1992) may be adopted:

AASTHO Soil Group	Unified Soil Group	Maximum Allowable Weight Loss %
A-1-a	GW, GP, GM, SW, SP, SM	14
A-1-b	GM, GP, SM, SP	14
A-2	GM, GP, SM, SC	14*
A-3	SP	14
A-4	CL, ML	10
A-5	ML, MH, CH	10
A-6	CL, CH	7
A-7	OH, MH, CH	7

*10% is the maximum allowable weight loss for A-2-6 and A-2-7 soils

Test Sheet for Durability

Durability Wetting And Drying (As Per IS :4332,Part-4)					
Project :			Client:		
Sample ID:			Date of Receiving:		
Source:			Date of Casting:		
Location:			Final Testing Date:		
Material Description:					
Sample-1			Sample-2		
Initial Weight :			Initial Weight :		
Cycle No.	**Weight Loss After Each Cycle (g.)**	**% Loss**	**Cycle No.**	**Weight Loss After Each Cycle (g.)**	**% Loss**
1 . . 12			1 . . 12		
Remarks:					

ANNEXURE-II B
DETERMINATION OF ELASTIC MODULUS "E"
(Refer Clause 3.3 and 4.2)

Determination of elastic modulus of the mix to be used in design of pavements is of paramount importance to replicate the performance on field. The following methods to arrive at the design modulus are described in this section:

Method 1:- Correlation of unconfined compressive strength and elastic modulus.

Method 2:- Determination of elastic modulus by third point beam load test.

For the determination of unconfined compressive strength, IS: 4332 (Part V)-1970 Determination of Unconfined Compressive Strength of Stabilized Soils is to be followed. The selection of sample type depends upon the gradation of samples that is to be stabilized:

a) Fine-Grained - Not less than about 90 per cent of the soil passing a 2.36 mm IS Sieve.
b) Medium-Grained - Not less than about 90 per cent of the soil passing a 20 mm IS Sieve
c) Coarse-Grained - Not less than about 90 per cent of the soil passing a 40 mm IS Sieve.

Table A: Standard Mould for determination of Unconfined Compressive Strength

	Fine Grained	**Medium Grained**	**Coarse Grained**
Mould Type	Cylindrical	Cylindrical	Cube
Mould Size	100 mm High x 50 mm Mean Diameter	200 mm High x 100 mm Mean Diameter	150 mm ± 0.2 mm

It should be noted that in the UCS test the results can be affected by both the size and shape of the sample tested, e.g. a cube or cylinder specimen. The results are often converted to those for 150 mm cube by multiplying the result with a correction factor. Some correction factors are given in table below:

Table B: Conversion Factors for UCS Test

Specimen Shape and Size	**Correction Factor (to 150 mm cube)**
Cube –150 mm	1.00
Cube –100 mm	0.96
Cylinder – 200 mm x 100 mm mean Dia.	1.25
Cylinder – 142 mm x 71 mm mean Dia.	1.25
Cylinder – 115.5 x 105 mm mean Dia.	1.04
Cylinder – 127 mm x 152 mm mean Dia.	0.96

The equipment's available these days are supplying the results in two units, one in Kilogram – Force and other in Newton. The unit majorly used in design of pavement with IITpave software is MPa for UCS and Elastic modulus. Thus the care must be administered to convert the test values to MPa before applying the values in design.

As per Section 7.2.2.2 of IRC:37-2012 (for Stabilized Sub base)

"The relevant design parameter for bound sub-bases is the Elastic Modulus E, which can be determined from the unconfined compressive strength of the material. In case of cementitious granular sub-base having a 7-day UCS of 1.5 to 3 MPa, the laboratory based E value (AUSTROADS) is given by the following equations:

Ecgsb = 1000 * UCS ……A1

Where UCS = 28 day strength of the cementitious granular material

Equation A1 gives a value in the range of 2000 to 4000 MPa. Since the sub-base acts as a platform for the heavy construction traffic, low strength cemented sub-base is expected to crack during the construction and a design value of 600 MPa is recommended for the stress analysis. Poisson's ratio may be taken as 0.25.

If the stabilized soil sub-bases have 7-day UCS values in the range 0.75 to 1.5 MPa, the recommended E value for design is 400 MPa with Poisson's ratio of 0.25.

It is also to be noted that "Where commercially available stabilizers are used, the stabilized material should meet additional requirements of leachability and concentration of heavy metals apart from the usual requirements of strength and durability."

For Stabilized base, section 7.3.2 "Cementetious Bases" reads

"7.3.2 *Cementitious bases*

7.3.2.1 Cemented base layers may consist of aggregates or soils or both stabilized with chemical stabilizers such as cement, lime, lime-flyash or other stabilizers which are required to give a minimum strength of 4.5 to 7 MPa in 7/28 days. While the conventional cement should attain the above strength in seven days (IRC:SP:89-2010(30)), lime or lime-flyash stabilized granular materials and soils should meet the above strength requirement in 28 days since strength gain in such materials is a slow process. Though the initial modulus of the cementitious bases may be in the range 10000 to 15000 MPa, the long term modulus of the cemented layer may be taken as fifty per cent of the initial modulus due to shrinkage cracks and construction traffic (65, 66). Australian guidelines recommend use of Equation 7.2 for the cemented layer. Curing of cemented bases after construction is very important for achieving the required strength as described in IRC:SP:89 and curing should start immediately by spraying bitumen emulsion or periodical mist spray of water without flooding or other methods.

7.3.2.2 Strength parameter

Flexural strength is required for carrying out the fatigue analysis as per fatigue equation. MEPDG suggests that the modulus of rupture for chemically stabilized bases can be taken as 20 per cent of the 28 day unconfined compressive strength. The same is recommended *in these guidelines. The following default values of modulus of rupture are recommended for cementitious bases (MEPDG).*

Cementitious stabilized aggregates – 1.40 MPa

Lime—flyash-soil – 1.05 MPa

Soil cement – 0.70 MPa

Poisson's ration of the cemented layers may be taken as 0.25."

Determination of elastic modulus beam load test

Elastic Modulus test are conducted in order to check whether stabilized mixture layer act as flexible or rigid, so that if the Modulus of Elasticity is high, the pavement consisting of stabilized layer and bituminous layer will be considered as semi-rigid and then the suitability of Stabilized layer as a base layer will be compared with respect to semi rigid pavement. The equipment shall be computerized cyclic beam loading set up. To determine the flexural strength of casted beams, it consists of three points loading, and the test shall be conducted at different amplitude and frequencies for finding the maximum elasticity modulus. The recommended specimen sizes, to be used in Laboratory are 500×100×100 mm and 300×75×75 mm.

Procedure: Soil-Stabilizer shall be mixed either by hand or in a suitable laboratory mixer in batches of such size as to leave ten per cent excess after molding test specimens. This material shall be protected against loss of moisture, and a representative part of it shall be weighed and dried in the drying oven to constant weight to determine the actual moisture content of the Soil-Stabilizer mixture. When the Soil-Stabilizer mixture contains aggregate retained on the 4.75 mm sieve, the sample for moisture determination shall weigh at least 500 g and shall be weighed to the nearest gram. If the mixture does not contain aggregate retained on the 4.75 mm sieve, the sample shall weigh at least 100 g and shall be weighed to the nearest 0.1 g. The batch shall be mixed in a clean, damp, metal pan or on top of a steel table, with a blunt brick-layer's trowel, using the following procedures:

a) Calculated amount of water to give moisture content 2 per cent less than the required final moisture content should be added to the soil passing 4.75 mm IS Sieve, thoroughly mixed and kept in a sealed container to avoid moisture loss overnight for uniform distribution of moisture.

b) The additional water required for bringing the moisture to the required level should be calculated. The calculated weight of the moist soil and stabilizer required for making the specimens should be mixed thoroughly. The remaining quantity of water to make up the required moisture content of the Soil-Stabilizer mixture should be added and thoroughly mixed.

c) The saturated surface-dry coarse fraction of the soil shall be added and the entire batch mixed until the coarse fraction is uniformly distributed throughout the batch.

Divide it into three equal batches of predetermined weight of uniformly mixed Soil-Stabilizer to make a beam of the designed density. Place one batch of the material in the mould and level by hand. When the Soil-Stabilizer contains aggregate retained on the 4.75 mm sieve, carefully spade the mix around the sides of the mould with a thin spatula. Compact the Soil-Stabilizer initially from the bottom up by steadily and firmly forcing (with little impact) a square-end cut 12 mm diameter smooth steel rod repeatedly, through the mixture from the top down to the point of refusal. Approximately 90 rods distributed uniformly over the cross-section of the mould are required; take care so as not to leave holes in clayey Soil-Stabilizer mixtures. Level this layer of compacted Soil-Stabilizer by hand and place and compact layers two and three in an identical manner. The specimen at this time shall be approximately 95 mm high. Place the top plate of the mould in position and remove the spacer bars. Obtain. Final compaction with a static load applied by the compression machine or Compression frame until the height of 75 mm is reached. Immediately after compaction, carefully dismantle the mould and remove the specimen onto a smooth, rigid wood or sheet metal pallet. Flexural test of moist cured specimens shall be made as soon as practicable after removing from the moist room, and during the period between removal from the moist room and testing, the specimens shall be kept, moist by the wet burlap or blanket covering.

Turn the specimen on its side with respect to its molded position (with the original top and bottom surfaces as molded perpendicular to the testing machine bed) and center it on the lower half-round steel supports, which shall have been spaced apart a distance of three times the depth of the beam. Place the load applying block assembly in contact with the upper surface of the beam at the third points between the supports refer **Photo 5**. Carefully align the center of the beam with the center of thrust of the spherically seated head block of the machine. As this block is brought to bear on the beam-loading assembly, rotate its movable portion gently by hand so that uniform seating is obtained. Apply the load continuously and without shock with a screw power testing machine, with the moving head operating at approximately 1.2 mm/min. With hydraulic machines adjust the loading to such a constant rate that the extreme fiber stress is within the limits of 7 ± 0.4 kg/cm^2/min. Record the total load at failure of the specimen to the nearest 3 kg. Make measurements to the nearest 0.2 mm to determine the average width and depth of the specimens at the section of failure.

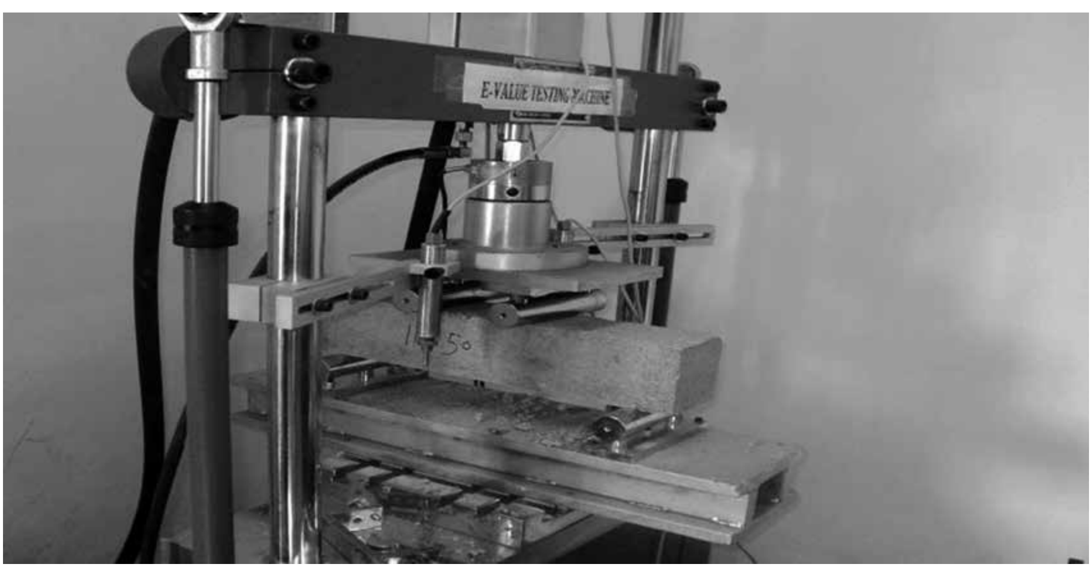


Photo 5 E-Value Test in Progress

Calculation and Report: If the fracture occurs within the middle third of the span length, calculate the modulus of rupture as follows:

$$R = Pl/bd^2 \text{ -- (weight of beam neglected)}$$

$$R = (P + 3W/4)\ l/bd^2 \text{ (weight of beam taken into account)}$$

Where,

R = modulus of rupture in kg/cm^2,

P = maximum applied load in kg,

l = span length in cm,

b = average width of specimen in cm,

d = average depth of specimen in cm, and

W = weight of the specimen in kg.

If the fracture occurs outside the middle third of the span length by not more than 5 per cent of the span length, calculate the modulus of rupture as follows:

$$R = 3Pa/bd^2$$

Where,

a = distance between line of fracture and the nearest support, measured along the center line of the bottom surface of the beam (as tested).

The report shall include the following:

a) Specimen preparation details;
b) Specimen identification number;
c) Average width and depth at section of failure to the nearest 0.2 mm;
d) Maximum load, to the nearest 5 kg;
e) Modulus of rupture calculated to the nearest 0.5 kg/cm^2;
f) Defects, if any, in specimen;
g) Age of specimen; and
h) Moisture content at time of test.

Sample Calculation

<Sample Description> % Material + % Stabilizer

Test Type: Flexure

Sample Id:

Test Date:

Sample Type Id: 0

Sample Height:100(mm)

Sample Width:100(mm)

Sample Length:500(mm)

Sample Diameter: -(mm)

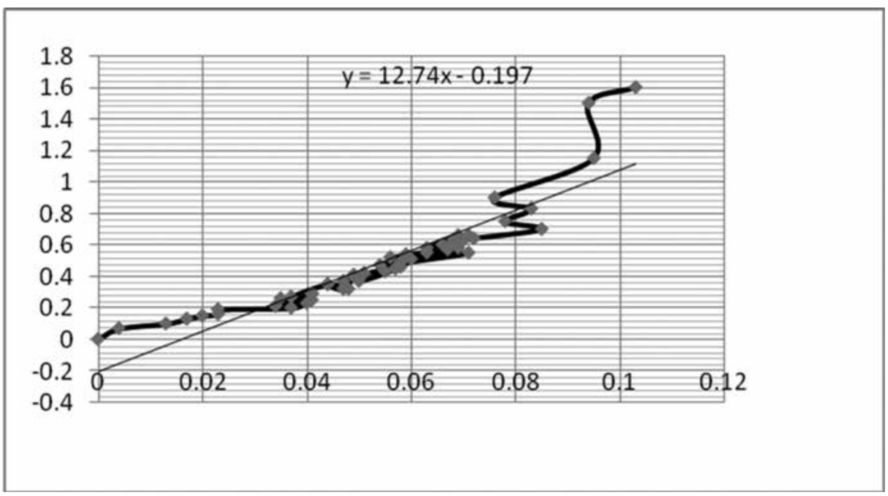
Sample Area:50000(Sq. mm)

Sample Weight... (Kg)

Sample Age:28 days Cured

Rate of Loading:0.01 ((KN/Sec))

Testing Person :



Graph: Load versus Displacement Graph

Table: Calculation of E-Value

Calculation of E-Value				
1	Failure Load (P)			KN
2	Corresponding Disp. (d)			Mm
3	Dimension of Beam	Length (L)		Mm
		Breadth (B)		Mm
		Width (D)		Mm
4	Avg. P'=P/d (from graph)			KN/mm
5	Failure Load (P)			N
6	Effective Length of Beam (L)			Mm
7	Moment of Inertia = I= $(B*D^3/12)$			mm^4
8	L/3=a			Mm
9	E= $Pa(3L^2-4a^2)/24*I$			MPa

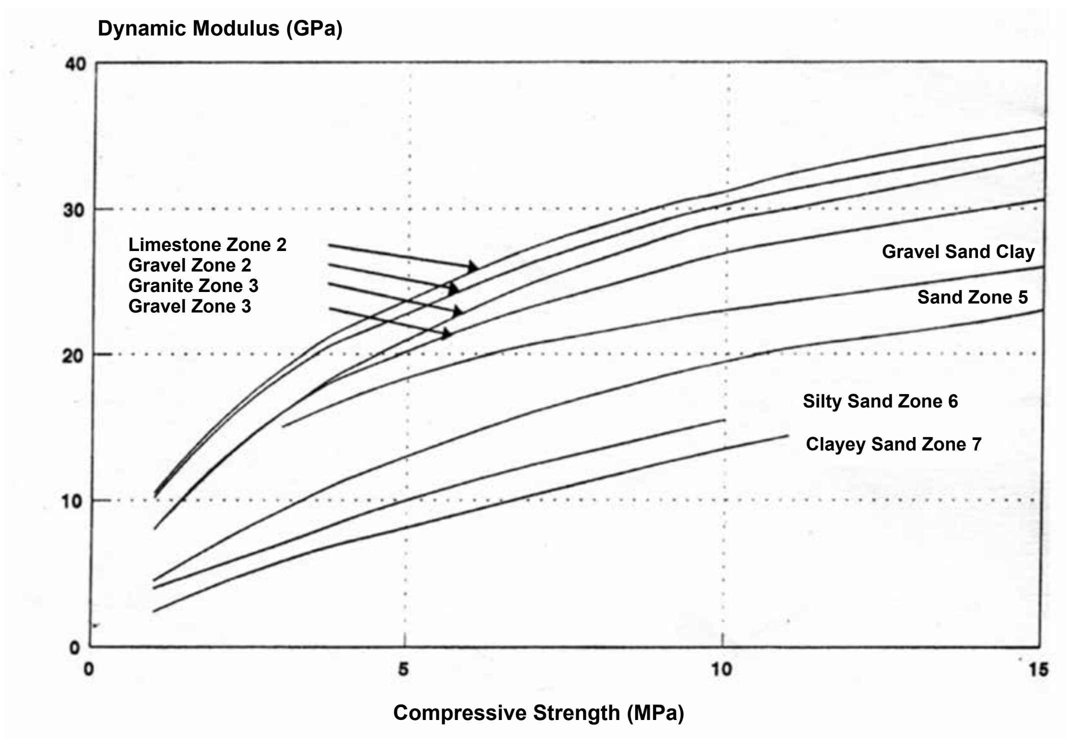
The combinations of the seating loads applied for dynamic loading should be suitably adjusted.

The factor of safety 1.5 to be considered for design the elastic modulus obtained with beam dynamic test.

Considering beam test apparatus is not commonly available it is recommended to keep the basis of E value as UCS test which is more commonly available across various laboratories in country.

At the same time the commercial stabilizers must develop their own fatigue equation and get it verified by Government institutes like IIT.

For CCS a relationship as shown below needs to be developed between compressive strength and elastic modulus



Relationship between dynamic modulus and compressive strength (at 28 days) for some cement treated materials (Croney, 1998)

ANNEXURE – III A
TYPICAL SECTIONS

(Refer Clause 4.3)

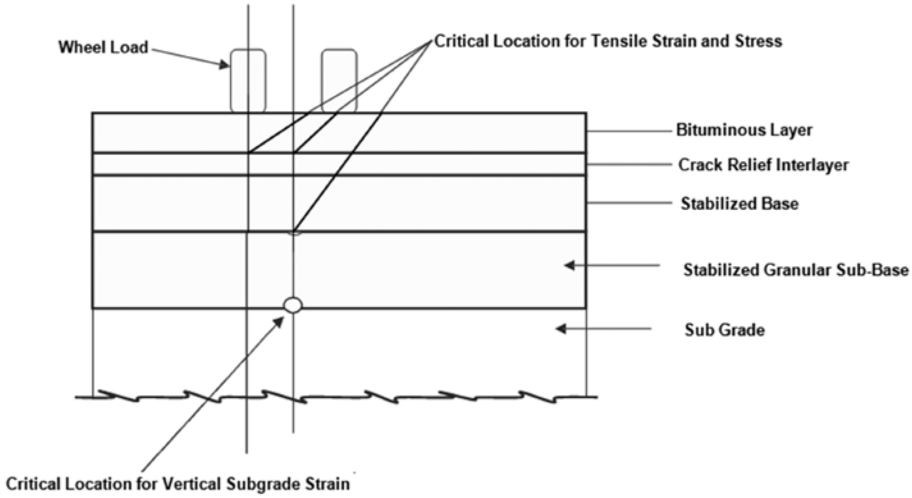


Fig. 2 Bituminous Pavements with Stabilized Base and Stabilized Granular Sub-base with Crack Relief Interlayer

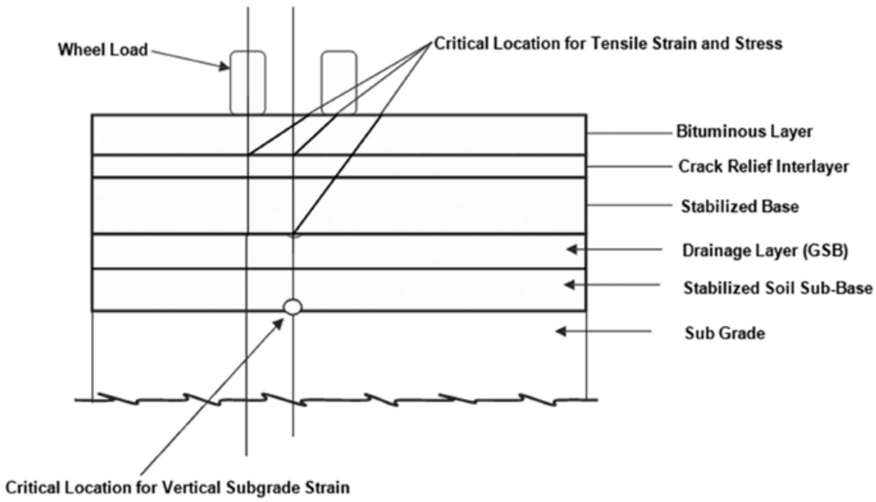


Fig. 3 Bituminous Pavements with Stabilized Base and Stabilized Soil Sub-base with Crack Relief Interlayer and Drainage Layer

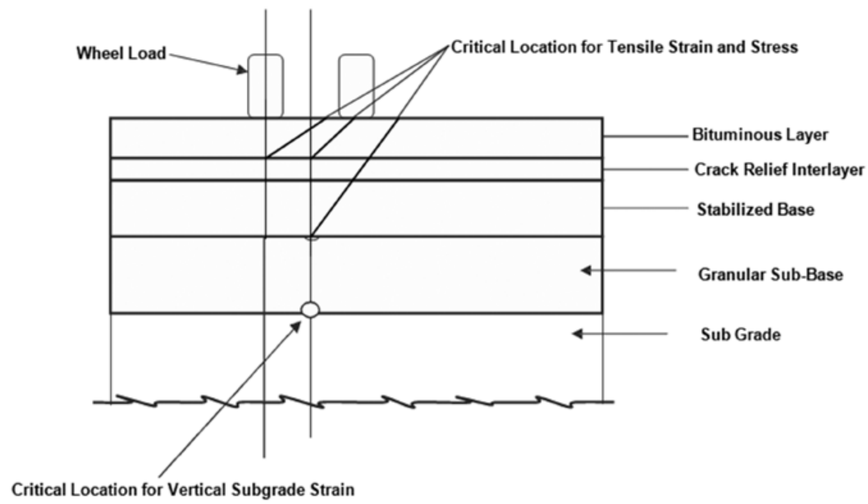


Fig. 4 Bituminous Pavements with Stabilized Base and Granular Sub-base with Crack Relief Interlayer

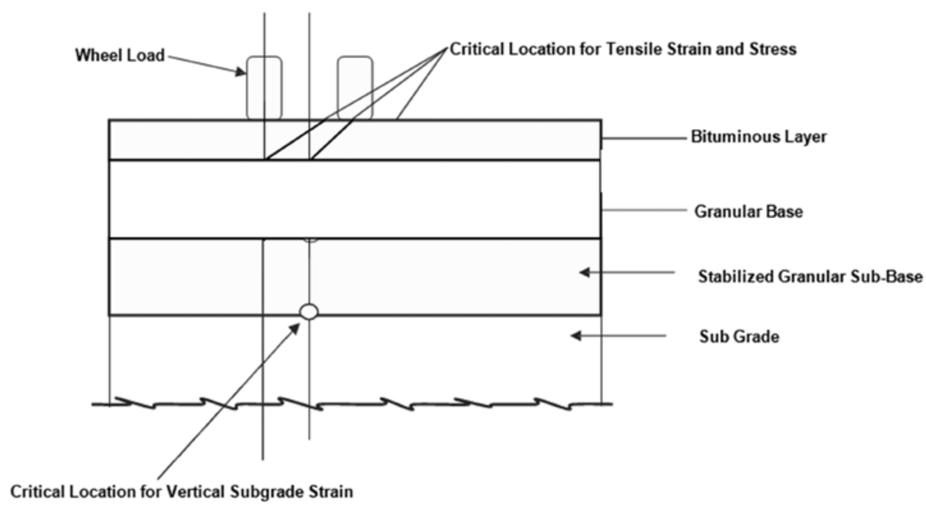


Fig. 5 Bituminous Pavements with Granular Base and Stabilized Granular Sub-base

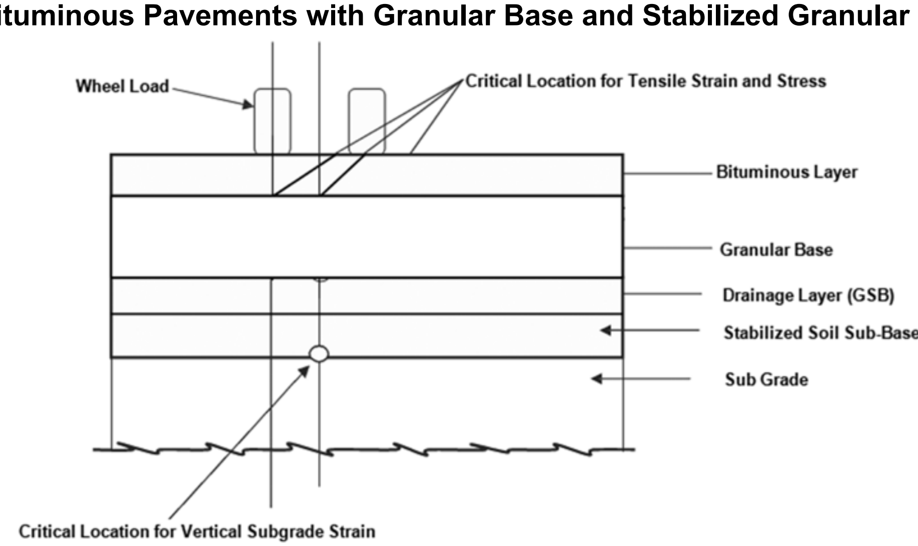


Fig. 6 Bituminous Pavements with Granular Base and Stabilized Soil Sub-base with Drainage Layer

ANNEXURE-III B
MIX DESIGN EXAMPLE
(Refer Clause 4.3)

INPUT PARAMETERS

Design Traffic Loading (MSA)

The new composite pavement has been designed for full design life i.e. 50 MSA as per traffic projections.

Load Location

A global coordinate system is used to define load locations, the layered system geometry and the points below the road surface at which results are required. The global coordinate system is also used to describe the resultant displacements and stress and strain tensors. The X-axis is usually taken as the direction transverse to the direction of vehicle travel. The Y-axis is then parallel to the direction of vehicle travel.

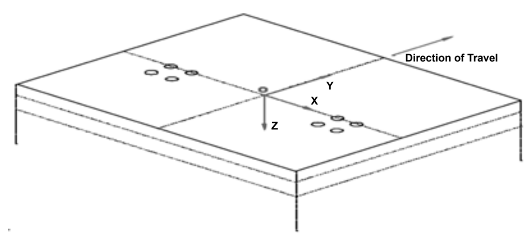


Fig. 7 Global Coordinate System

The Z-axis is vertically downwards with Z = 0 on the pavement surface.

Two alternative formats are available for specifying the points to be used for results calculation:

- An array of equally spaced points along a line parallel to the X-axis;
- A grid of points with uniform spacing in both the X-direction and the Y-direction.

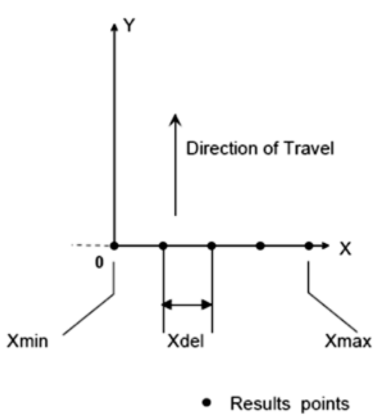


Fig. 8 Coordinates for Results Defined by a Line of Equally Spaced Points

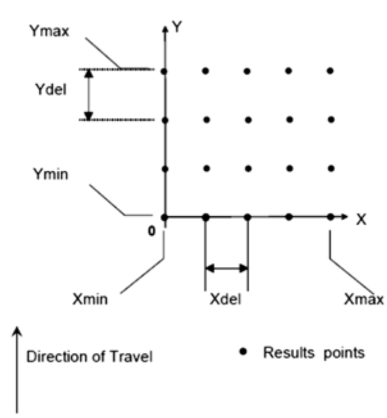


Fig. 9 Coordinates for Results Defined by a Uniform Grid of Points

By the alternate of an array of equally spaced points along a line parallel to the X-axis, the following inputs are opted:

Option 1: Stabilized Base with Granular Sub Base

Z axis: 100.00, X axis: 0.00, Y axis: 0.00

Z axis: 340.00, X axis: 0.00, Y axis: 0.00

Z axis: 590.00, X axis: 0.00, Y axis: 0.00

Option 2: Stabilized Base with Stabilized Sub Base

Z axis: 100.00, X axis: 0.00, Y axis: 0.00

Z axis: 250.00, X axis: 0.00, Y axis: 0.00

Z axis: 400.00, X axis: 0.00, Y axis: 0.00

Design CBR

Subgrade strength has the profound influence on the performance of pavement as well the cost of the project too. CBR of 7 per cent has been considered for the determination of new pavement composition.

Material Properties

Elastic Modulus (E Value)

The modulus value of the stabilized base composition for base has been derived from laboratory analysis by 4 point beam method. The average E-Value found is 2600 MPa. For analysis factor of safety is taken as 1.5.

The E-value for design is 2600/1.5 = 1733.33 say **1700 MPa**

Poisson's Ratio

The Poisson's ratios taken for analysis are shown in Table below:

Table : Poisson's Ratio for Different Layers

Sr. No.	Layers	Poisson's Ratio
1	Bituminous Layers	0.35
2	Stabilized Aggregate Base	0.25
3	Stabilized Sub base	0.25
4	Granular Sub Base	0.35
5	Sub Grade	0.35

Fatigue Criteria

Bituminous Surfacing

Considering the temperature 35^{o}C & VG40 bitumen with reference to IRC:37 page 23, the elastic modulus of bituminous layer is taken as 3000 MPa.

Now if we put the E-value in given fatigue equation, further derive as

$$Nf = 2.021 * 10-04 \times [\, 1/έt] \; 3.89 * [1/MR] 0.854$$

Stabilized Aggregate Layer

The equation for cement stabilized referred in IRC:37 is

$$N = RF[(113000/ E^{.804} + 191)/ έt\,]^{12}$$

Where,

RF= reliability factor for cementetious material for failure against fatigue

N= Fatigue life of cementetious material

E= Elastic modulus of cementetious material

έt= tensile strain in the cementetious layer microstrain

Rutting Equation

As large number of data for rutting failure of pavements were obtained from the Research Scheme of MoSRT&H and other research investigations. Indian Roads Congress set the allowable rut depth as 20 mm, the rutting equation was obtained as:

$$N = 4.1656 \times 10^{-08} [1/έv]^{4.5337}$$

$$N = 1.41 \times 10^{-08} [1/έv]^{4.5337}$$

Where,

N = Number of cumulative standard axles to produce rutting of 20 mm

έv = Vertical Subgrade Strain (micro strain)

PROPOSED PAVEMENT DESIGN WITH STABILIZER

Considering all parameters and equations given in previous sections of this document, the software was run. The output sheet of software and the final design proposed with aggregate crack relief interlayer is given below:

Table : Proposed Design with Stabilizer, Option 1 Stabilized Base & Granular Sub Base

Layer Designation	Thickness (mm)
Bituminous Concrete	50
Dense Bituminous Macadam	50
Stabilized Base	240
Granular Sub Base	250

Table : Proposed Design with Stabilizer, Option 2 Stabilized Base & Stabilized Sub Base

Layer Designation	Thickness (mm)
Bituminous Concrete	50
Dense Bituminous Macadam	50
Stabilized Base	150
Stabilized Sub Base	150

IIT PAVE CALCULATION FOR OPTION 1

```
No. of layers              4
E values (MPa)        3000.00 1700.00  146.00   61.00
Mu values                0.350.250.350.35
thicknesses (mm)       100.00  240.00  250.00
single wheel load (N) 20000.00
tyre pressure (MPa)      0.56
Dual  Wheel
  Z        R      SigmaZ      SigmaT      SigmaR      TaoRZ       DispZ      epZ        epT        epR
100.00    0.00-0.3263E+00-0.8184E-02-0.2949E-01-0.3108E-01 0.3198E+00-0.1044E-03 0.3878E-04 0.2919E-04
100.00L   0.00-0.3263E+00-0.2521E-01-0.3825E-01-0.3108E-01 0.3198E+00-0.1826E-03 0.3878E-04 0.2919E-04
100.00  155.00-0.1367E+00-0.4357E-01-0.2195E+00-0.1851E+00 0.3202E+00-0.1489E-04 0.2704E-04-0.5213E-04
100.00L 155.00-0.1367E+00-0.2019E-01-0.1279E+00-0.1851E+00 0.3202E+00-0.5866E-04 0.2704E-04-0.5213E-04
340.00    0.00-0.2645E-01 0.2045E+00 0.1658E+00-0.5735E-02 0.2976E+00-0.7003E-04 0.9982E-04 0.7136E-04
340.00L   0.00-0.2645E-01 0.6520E-02 0.3446E-02-0.5735E-02 0.2976E+00-0.2051E-03 0.9980E-04 0.7138E-04
340.00  155.00-0.2814E-01 0.2183E+00 0.1783E+00-0.1069E-01 0.3043E+00-0.7488E-04 0.1063E-03 0.7694E-04
340.00L 155.00-0.2814E-01 0.7018E-02 0.3842E-02-0.1069E-01 0.3043E+00-0.2188E-03 0.1063E-03 0.7695E-04
590.00    0.00-0.1240E-01 0.1135E-01 0.1001E-01-0.1666E-02 0.2585E+00-0.1362E-03 0.8345E-04 0.7111E-04
590.00L   0.00-0.1236E-01 0.8599E-03 0.2785E-03-0.1666E-02 0.2585E+00-0.2092E-03 0.8344E-04 0.7058E-04
590.00  155.00-0.1297E-01 0.1190E-01 0.1108E-01-0.2106E-02 0.2626E+00-0.1439E-03 0.8606E-04 0.7845E-04
590.00L 155.00-0.1297E-01 0.9063E-03 0.5625E-03-0.2106E-02 0.2626E+00-0.2211E-03 0.8605E-04 0.7845E-04
```

IIT PAVE CALCULATION FOR OPTION 2

```
No. of layers              4
E values (MPa)         3000.00 1700.00  600.00   61.00
Mu values                 0.350.250.250.35
thicknesses (mm)        100.00  150.00  150.00
single wheel load (N) 20000.00
tyre pressure (MPa)       0.56
Dual  Wheel
  Z        R      SigmaZ      SigmaT     SigmaR     TaoRZ      DispZ      epZ        epT        epR
100.00    0.00-0.3185E+00 0.1235E-01-0.1077E-01-0.3430E-01 0.3537E+00-0.1064E-03 0.4253E-04 0.3213E-04
100.00L   0.00-0.3185E+00-0.1448E-01-0.2863E-01-0.3430E-01 0.3537E+00-0.1810E-03 0.4253E-04 0.3213E-04
100.00  155.00-0.1302E+00-0.2186E-01-0.1982E+00-0.1960E+00 0.3558E+00-0.1774E-04 0.3102E-04-0.4831E-04
100.00L 155.00-0.1302E+00-0.9051E-02-0.1169E+00-0.1960E+00 0.3558E+00-0.5807E-04 0.3102E-04-0.4831E-04
250.00    0.00-0.6276E-01 0.1800E+00 0.1405E+00-0.2130E-01 0.3368E+00-0.8405E-04 0.9443E-04 0.6544E-04
250.00L   0.00-0.6276E-01 0.4998E-01 0.3607E-01-0.2130E-01 0.3368E+00-0.1404E-03 0.9443E-04 0.6543E-04
250.00  155.00-0.5883E-01 0.1875E+00 0.1310E+00-0.5461E-01 0.3448E+00-0.8145E-04 0.9966E-04 0.5816E-04
250.00L 155.00-0.5884E-01 0.5348E-01 0.3356E-01-0.5461E-01 0.3448E+00-0.1343E-03 0.9966E-04 0.5816E-04
400.00    0.00-0.1934E-01 0.9622E-01 0.8084E-01-0.3059E-02 0.3203E+00-0.1060E-03 0.1347E-03 0.1027E-03
400.00L   0.00-0.1932E-01 0.1460E-02 0.1211E-04-0.3060E-02 0.3203E+00-0.3252E-03 0.1347E-03 0.1027E-03
400.00  155.00-0.2050E-01 0.1031E+00 0.8904E-01-0.4962E-02 0.3278E+00-0.1142E-03 0.1433E-03 0.1140E-03
400.00L 155.00-0.2052E-01 0.1686E-02 0.3587E-03-0.4967E-02 0.3278E+00-0.3482E-03 0.1433E-03 0.1140E-03
```

Table : Strain Comparison

Sr. No.	Layer	Permissible Micro Strain as per fatigue equations given in IRC:37	Location of Strain	Actual Micro-strain Values Obtained	Remarks
OPTION 1					
1	Bituminous Layer	155.28	Bottom of Layer	38.78	Safe
2	Stabilized Base	108.79	Bottom of Layer	106.30	Safe
3	Subgrade	371.69	Top of Subgrade	221.10	Safe
OPTION 2					
1	Bituminous Layer	155.28	Bottom of Layer	42.53	Safe
2	Stabilized Base	108.79	Bottom of Layer	99.66	Safe
3	Subgrade	371.69	Top of Subgrade	348.20	Safe

CHECKING OF THE SAFETY OF CEMENTITIOUS BASE DUE TO OVERLOADING

Since there are plenty of single, tandem and tridem axle loads which are far higher than standard axle load used for pavement design, thickness of cement layer must be checked for sudden fracture of the brittle material like cemented base due to higher axle loads using cumulative damage principle. One tandem axle is taken as two single axles and one tridem axle is taken as three axles carrying equal weight since the interference of stresses at the cemented base are little due to axle loads being about 1.30 m to 1.40 m apart. All multiple axle vehicles are combination of single, tandem and tridem axles. The axle load data can be classified or grouped in such a manner that all tandem and tridem axles can be converted into single axle repetition for stress analysis. The axle load spectrum of the traffic data is as follows.

Axle load in KN	% of Axles	Expected repetitions	Stress, in MPa	Stress Ratio	Fatigue Life	Fatigue Life Consumed
Single Axle						
85	31.72	15529536	0.100	0.071	8.24E+10	0.00019
90	6.34	3105907	0.106	0.076	7.31E+10	0.00004
100	4.53	2218505	0.112	0.080	6.49E+10	0.00003
110	2.72	1331103	0.118	0.084	5.76E+10	0.00002
120	2.11	1035302	0.124	0.089	5.11E+10	0.00002
130	1.51	739502	0.130	0.093	4.53E+10	0.00002
140	0.91	443701	0.136	0.097	4.02E+10	0.00001
150	0.00	0	0.142	0.101	3.57E+10	0.00000
160	0.00	0	0.148	0.106	3.17E+10	0.00000
Tandem Axle						
170	12.08	5916014	0.154	0.110	2.81E+10	0.00021
180	2.72	1331103	0.160	0.114	2.49E+10	0.00005
190	2.42	1183203	0.166	0.119	2.21E+10	0.00005
200	6.04	2958007	0.172	0.123	1.96E+10	0.00015
210	3.63	1774804	0.178	0.127	1.74E+10	0.00010
220	5.74	2810106	0.184	0.131	1.54E+10	0.00018
230	6.65	3253808	0.190	0.136	1.37E+10	0.00024
240	5.74	2810106	0.196	0.140	1.22E+10	0.00023
250	3.02	1479003	0.202	0.144	1.08E+10	0.00014
260	0.60	295801	0.208	0.149	9.57E+09	0.00003
270	1.21	591601	0.214	0.153	8.49E+09	0.00007
280	0.30	147900	0.220	0.157	7.53E+09	0.00002
290	0.00	0	0.226	0.161	6.69E+09	0.00000
300	0.00	0	0.232	0.166	5.93E+09	0.00000
					Cumulative Fatigue :	**0.00181**

It can be seen that total fatigue damage is less than 1. Hence the pavement is safe and Cementitious layer will not crack prematurely. There is no superposition of stresses in Cementitious layer due to location of this layer at shallow depth.

ANNEXURE-IV

RECOMMENDED SPECIALIZED IN-SITU SPREADING AND MIXING MACHINERY FOR STABILIZATION

(Refer Clause 5.2)

Spreader

Photo 6 Tractor Mounted Spreaders

Photo 7 Truck Mounted Spreaders

Mixing Machinery

Photo 8 Tractor Power Driven

Photo 9 Self Power Driven